Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Proposed Changes in the Commission's Rules	)	ET Docket No. 03-137
Regarding Human Exposure to	)	
Radiofrequency Electromagnetic Fields	)	

To the Commission:

Comments of Richard A. Tell

1. Richard A. Tell, President of the firm of Richard Tell Associates, Inc. submits these Reply Comments in response to those filed by various contributors to the Commission's September 8, 2003, Notice of Proposed Rulemaking (NPRM) in the matter of Proposed Changes in the Commissions Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields, ET Docket No. 03-137. Richard Tell has 37 years of experience directly related to matters of radiofrequency (RF) safety, with 20 of those years in service to the U.S. Environmental Protection Agency (EPA) and the last 17 years in private consulting practice of RF hazard identification, assessment, and resolution. He has been a participant in the Institute of Electrical and Electronics Engineers (IEEE) since the late 1960's and serves as Chairman of Subcommittee 2 (Subcommittee on Terminology, Units of Measurement, and Hazard Communications) of the IEEE's International Committee on Electromagnetic Safety (ICES) as well as Chairman of the ICES Subcommittee 4 Risk Assessment Working Group. Mr. Tell has provided RF safety support over the years to various large scale broadcast sites including the former World Trade Center, the Empire State Building, 4Times Square, Hancock Center, Tucson Mountain and high power international broadcast sites, etc., as well as to wireless telecommunications operators throughout the United States. His experience and background are known to the Commission through several contracts to the Office of Engineering and Technology on RF safety related projects. These reply comments are those of Richard A. Tell, personally, and not as a representative of the IEEE or any of its committees.

Categorical Exclusions

2. Numerous respondents have commented about the concept of categorical exclusion, the process by which certain classes of transmitters, such as those found in the wireless communications service, may be excused from routine compliance evaluations. My personal experience has been that this process, in many cases, would appear to be more

of an “apparent” relaxation of the efforts that transmitter operators should exercise rather than any real benefit. This opinion derives from the fact that in any case, the FCC expects all licensed transmitters to be operated in such a way as to prevent exposure of individuals exceeding the applicable MPE limits. For example, at paragraph 72 of the FCC’s Second Memorandum Opinion and Order and Notice of Proposed Rulemaking (FCC 97-303) is found the language: “However, we emphasize that all FCC-regulated transmitters are expected to comply with our applicable guidelines, **regardless of whether they are categorically excluded or not.**”[emphasis added]. This means that all licensed transmitters must always comply with the MPE limits adopted by the FCC and, hence, it makes little difference as to whether a transmitter is categorically excluded from “routine evaluation” or not when it comes to assessing compliance.

Spatial Averaging Issues

3. The fundamental basis of the MPE limits used by the FCC is control of the whole-body averaged specific absorption rate (SAR) in individuals exposed to RF fields as exemplified in the IEEE C95.1 standard and the exposure criteria recommended by the National Council on Radiation Protection and Measurements (NCRP Report 86). The derivation of the MPE limits made the assumption of uniform, whole-body exposure to the incident RF field. In reality, of course, uniform exposure of the whole body almost never occurs since, in the real world, RF fields are generally nonuniform, the result of reflections and scattering from the ground, other structures in the vicinity, and RF field radiation patterns of antennas. Compliance with the whole-body SAR criteria (for occupational/controlled and general public/uncontrolled exposures) that are associated with the MPE limits is best accomplished by assessing the spatially averaged value of the plane wave equivalent power density over the body dimensions.

4. For the measurement of spatially averaged plane wave equivalent power density to most accurately translate to whole-body averaged SAR, the exposure field should be characterized with a minimum of perturbation that can be introduced by the measurement process itself. This means that interactions between exposure fields and the observer should be reduced to the extent feasible. Such interactions, particularly in the VHF range, can be significant, especially when the incident field has a vertical polarization component and, hence, RF compliance measurements must always include consideration of how this field-body interaction may influence any conclusions formed on the basis of the measurements. In some cases, the observer influenced perturbation may lead to erroneously elevated or depressed indicated RF field values and, therefore, incorrect conclusions as to compliance.

5. The magnitude of these interactions can be significant. Extensive RF field measurements conducted on the elevated public walkway on the south tower at the former World Trade Center (WTC), for example, revealed that measures of the spatially averaged field varied by as much as a factor of five depending on the orientation of the observer performing the measurements relative to the incident RF fields. Generally, the greatest measured field will occur when the measurement probe is located between the field arrival direction and the observer’s body such that maximum reflected energy exists

at the probe location. With such a wide range in spatially averaged values of fields possible, it is clear why different individuals performing RF field measurements at the same location, using the very same instrumentation, may come to different conclusions about compliance; simply standing in a different orientation relative to the transmitting source can lead to substantially different measurement results. Figure 1 illustrates selected measurement results obtained at the World Trade Center for several alternative operating scenarios of the broadcast transmitters operating from the north tower of the WTC.

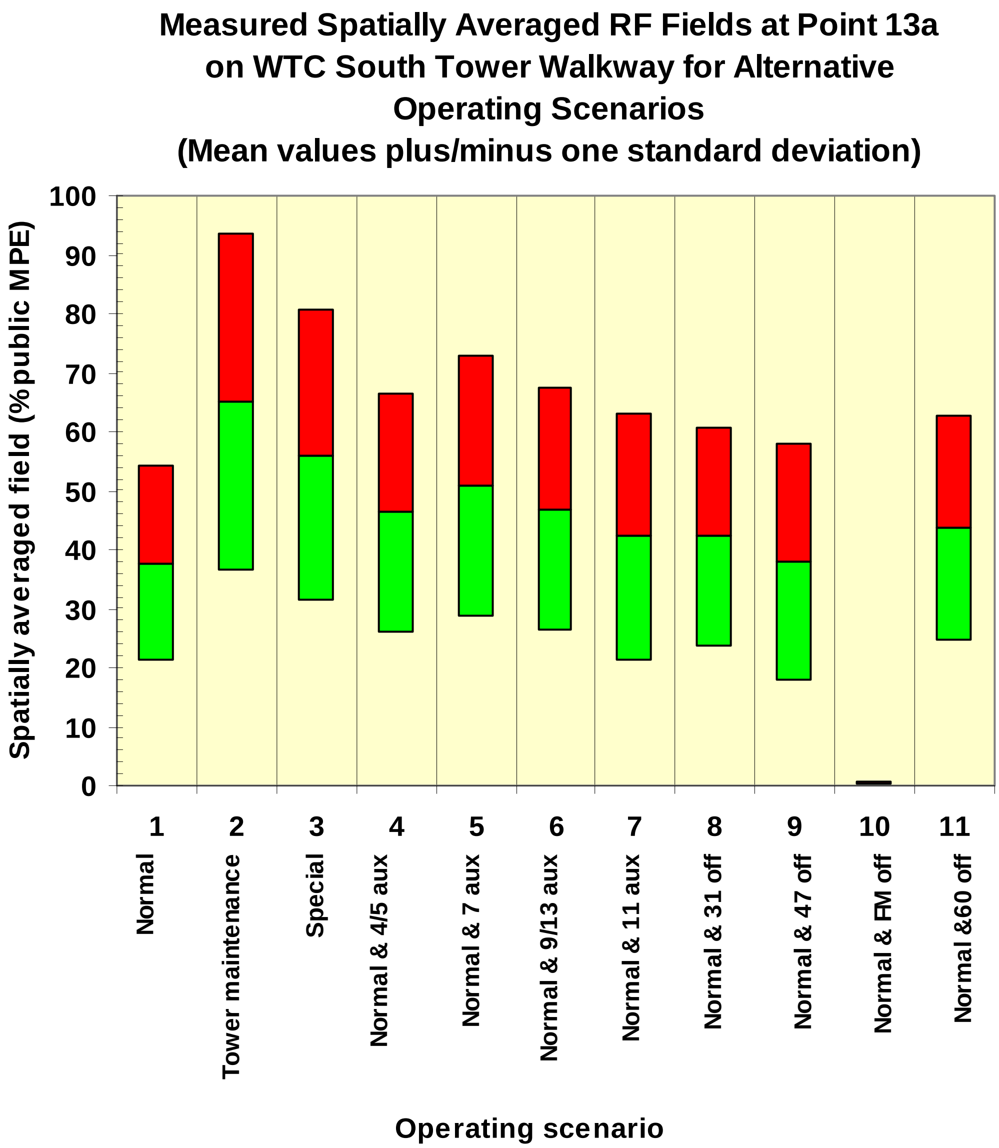

Figure 1. Example measurement data obtained at the former World Trade Center on the public walkway on the south tower. RF fields were produced by the broadcast stations operating from the north tower. Data is represented by mean and standard deviations of eight measurements at each point.

The results of multiple measures of spatially averaged fields are presented in Figure 1 in terms of the mean (overall average) and upper and lower standard deviations based on a total of eight separate measurements, each from a different orientation relative to the measurement point, approximately 45 degrees apart. The mean value of multiple measures of spatial averages is a better estimator of the unperturbed field at the measurement point than any single measurement, when there is detectable interaction between the field and the body.

6. Another example of body-field interaction can be seen in Figure 2.

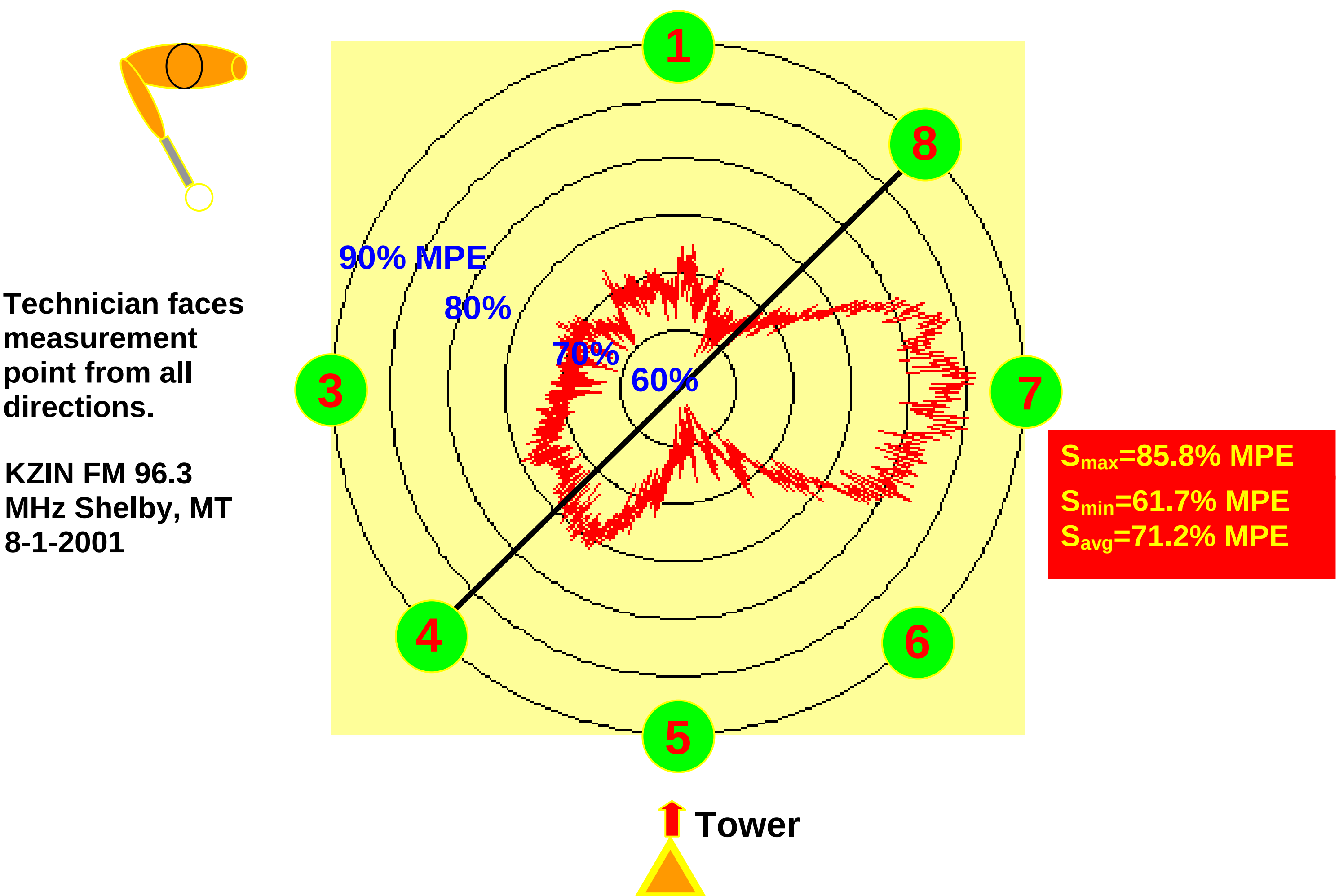

Figure 2. Illustrative measurement data obtained at FM radio station KZIN in Shelby, Montana. The observer held their arm out at a constant height above ground and slowly pivoted about the measurement point while the field probe was maintained at the height of the extended arm. Real-time measurement of the detected field was recorded to illustrate the impact of body interactions with the incident field. In this case, the field was strongly horizontally polarized and resulted in less interaction with the body than

found in measurements of more strongly vertically polarized fields. (Data presented were collected as a cooperative effort with Jim Hatfield of Hatfield and Dawson, Inc., Seattle, WA).

7. Figure 2 illustrates stronger interaction with the incident field when the observer stood such that their arm extended broadside to the FM antenna, resulting in greater local field perturbation near the probe. The probe made use of fiber optic cables to a remote computer readout system located 75 feet away.

8. These data illustrate the need for multiple measurements when spatially averaged field measurements become necessary and there is the likelihood of substantial field interactions with the body of the observer. This is predominantly the case when strong VHF fields are present and especially so if these fields are vertically polarized. In field surveys, when it is determined that spatial peak RF fields may approach or exceed the MPE limit, and there is evidence of potentially significant interaction between the observer and the fields, measurements to demonstrate compliance with the MPE limits should be performed as a series of spatially averaged values with from four to eight different orientations of the individual performing the measurement. As a practical matter, four such measurements, spaced 90 degrees apart, may be sufficient but the closer the overall average of the measurements is to the MPE limit, the greater the importance of using more measurements to obtain the mean value.

9. One question raised in the comments was whether measurements of spatially averaged fields should extend along a vertical axis, representing a standing person, or whether measurements should be performed at a series of points within a rectangular area representing the torso of the body, similar to recommendations contained in Canadian Safety Code 6 where the 35 cm wide by 125 cm tall rectangular measurement region extends only from 50 cm above the ground.

10. While it may appear more attractive to determine an area average for the field being measured (expressed as either a percentage of the MPE limit or the plane wave equivalent power density value), a more practical approach is the use of a simple vertical line extending from near the ground surface to a height of six feet. This opinion is based on two considerations: (a) maximizing the repeatability of the measurement process, and (b) ensuring that important spatial aspects of the field are properly included in the assessment of whole body spatial average exposure.

11. The repeatability of measurements of RF fields for FCC compliance purposes should be documented. This can be accomplished through repeated measurements at a specific location at the site being evaluated and calculation of the standard deviation of the multiple measurements, expressing the result as a percentage of the overall mean value. In outdoor locations, subject to the various factors that may affect measurements, there is a finite minimum variation associated with the measurement process that needs to be kept in mind. For example, measurement data obtained at the same Montana location described above, provide useful insight to the issue of how repeatable measurements might be under relatively stable and ideal environmental conditions. Using a RF non-

perturbing stand, a small electric field probe connected via a fiber optic cable to a computerized readout located some 75 feet from the measurement location was used to acquire repeated measures of the continuous RF field along a 2 meter vertical line. The probe was elevated at a constant rate while readings were obtained with the computer at a high recording rate and, after squaring of the electric field strength values, the spatially averaged value was obtained. This process yielded a nominal variation of 8%, this being the value <u>without any perturbing influence</u> of an observer at the measurement location. Hence, for the environment used for these test measurements of RF fields, it was not reasonable to expect that one could achieve better than about 8% in terms of repeatability. The more complex the measurement scenario for obtaining the spatial average, the greater the variability will inherently be. For this reason, a simple, straight vertical line represents the measurement scenario that will generally be the least susceptible to variation in repeated measurements. If an alternative, more complex measurement process is selected, it will be relevant to understand that measurements would likely contain more variability and this variability should be documented in any data acquired for assessing compliance with FCC RF rules.

12. Measuring fields over only a limited portion of the body will not result in the best estimate of the whole body averaged exposure. For example, depending on field distribution, limiting the spatial range of measurements can lead to an understatement of whole-body spatially averaged field exposure. RF field environments in which significant reflections exist from the ground can result in significant alteration of the spatial distribution of fields at the measurement location and will be a function of the orientation of the observer relative to the incident fields. Depending on the exact orientation of the observer, fields near the ground can be enhanced and at other orientations, fields at higher locations may be enhanced.

13. Figure 3 illustrates the results of a theoretical analysis for an RF field in the FM broadcast band incident on a conductive platform with a conductive cylinder placed at various locations relative to the measurement point. The cylinder was used to represent the body of an observer performing measurements. In each case, the spatially averaged field, in terms of plane wave equivalent power density, over a six foot height, was calculated and expressed as a percentage of the MPE limit. Curve 1 represents the case of no observer and the spatially averaged field has been normalized to a value of 100% of the MPE limit. Depending on the location of the surrogate observer, it can be seen that the spatial distribution of the field changes in character, sometimes being greater nearer the ground plane and sometimes being greater at higher elevations. Such changes in the local field are a function of the phase of the reflected fields relative to the incident field. When the surrogate observer is placed in front of the measurement point, blockage is apparent with the spatially averaged value of field dropping to just less than one-half of the unperturbed value. With the surrogate observer placed behind the measurement point, the spatially averaged field is increased to 180% of the unperturbed value. But, equally importantly, it can be seen that depending on the spatial averaging scheme chosen, in which lower elevation measurements might be omitted from the overall measurement, the resulting value measured could significantly underestimate the spatially averaged field to which the body is exposed. I recommend that vertical line spatial

averages be determined from near the ground or standing surface to a height of six feet to achieve the most meaningful estimate of field that would be proportional to the whole body averaged SAR that would result from the exposure.

14. IEEE C95.3-2002 recommends that measurements not be performed closer than 5 cm to any active source of RF fields. In the context of a reflective ground (or standing) surface, vertical line spatial averages should be performed with the field probe brought near the surface and raised to the relevant height.

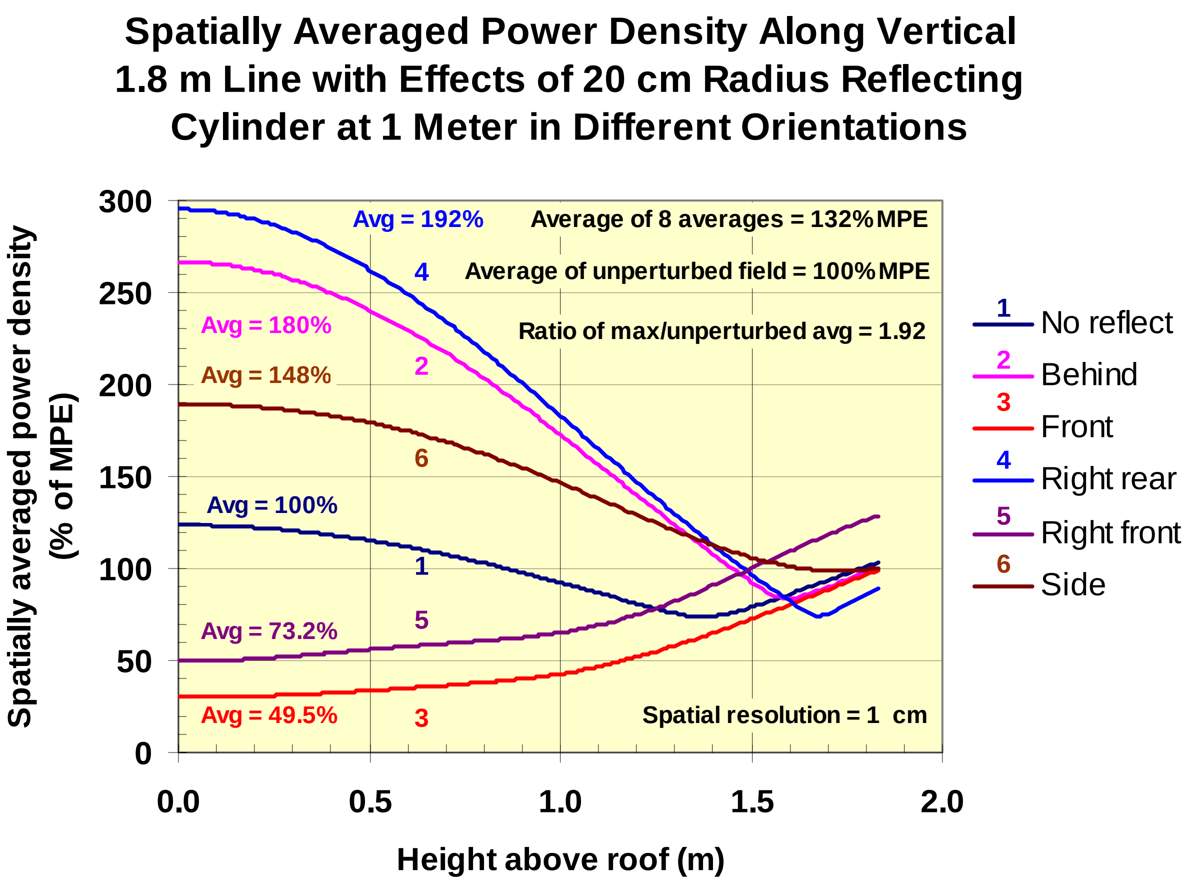

Figure 3. Calculated RF field variations as a function of height above a conducting plane with 100 MHz incident RF fields arriving from an angle of incidence of about 30 degrees. The influence of a conductive cylinder placed at different orientations about the calculation point illustrates the effect of field reflections on the field that would be measured with an isotropic probe.

15. One respondent commented that the only meaningful way to assess RF fields in a multifrequency environment is to make use of a spectrum analyzer type of device connected to calibrated antennas so that a frequency analysis of the incident fields could be performed. This is addressed in a later response about use of frequency shaped probes

but it should be noted that the use of antennas, because of their size, generally does not permit any useful spatial averaging to be accomplished.

Calculation Models

16. Some models in OET-65 do not take into account spatial averaging but yield maximum, point-in-space values of power density, leading to over-estimates of actual field levels. Some comments raised the issue of conservatism in models used in OET Bulletin 65 for estimating RF field magnitudes. Users of the document should be reminded that many of the formulas contained in OET Bulletin 65 yield values for the maximum, point-in-space power density that might exist were the reflected fields from the ground, or standing surface, constructively interfere with the incident fields. This can result in significant over-estimation of the field under many conditions. For example, use of far-field formulas often will lead to the declaration of areas at transmitter sites that greatly exceed the area within which RF fields may actually exceed MPE limits. This can result in unnecessary measures being taken to restrict access to these supposedly high field areas and can result in undue financial and operational impact.

17. Another example of how use of far-field modeling can lead to erroneous conclusions relative to compliance with FCC MPE limits is when the formulas are used to calculate the composite RF fields found at multi-frequency transmitter sites. A not uncommon approach to estimating the magnitude of RF fields at such sites is to sum the computed fields of all sources including the effect of possible reflections. This practice generally leads to substantial over-estimates of the aggregate field relative to the actual spatially averaged field that is necessary for compliance determination since all reflected waves are assumed to add in phase with one another; in practice, this will not be the case for multiple fields of different wavelengths since any reflected components will exhibit their own unique spatial characteristics and will not, in general, be in phase with one another. While subject to further evaluation, it is likely more correct to eliminate the use of so-called corrective ground reflection factors when making estimates of the magnitude of spatially averaged RF fields when multiple frequency emitters are involved. The FCC should emphasize that field estimates using ground reflection factors, when used in multi-frequency environments, can result in significant over-calculation of the actual field.

Use of Shaped Probes in Multifrequency Environments

18. In one comment, the position was taken that shaped probes cannot be usefully employed in multifrequency environments. The whole purpose of frequency shaped probes, in the first place, was to permit convenient measurement of multiple fields where it is difficult to control operation of individual sources. While frequency shaped probes cannot be conformed to the exact shape of the MPE limit curve, they can be manufactured to conform within a known and specified frequency response tolerance. For example, an uncertainty of ±2 dB is specified for one commonly used broadband probe. Such probes can, and are routinely, effectively used in assessing composite RF

fields at complex broadcast sites. Broadband probes are generally calibrated at multiple frequencies and correction factors are correspondingly recorded so that frequency specific measurements can be corrected to achieve the greatest possible accuracy. When measurements include significant contributions of two or more frequencies, it is not generally appropriate to apply a particular correction factor since it is not possible to know what the relative contributions of the various frequencies are to the composite RF field. In these cases, the maximum frequency response uncertainty of the probe must be used and assigned to the overall reading. If measurements with less uncertainty are required, then frequency specific measurements must be arranged for by controlling the activity of individual sources during the survey whereby frequency specific correction factors can be applied to the measurement of the individual fields. However, it must be recognized that such measurements of the total field are fraught with the challenge of performing multiple measures of spatially averaged fields at each relevant measurement point. When individual transmitters are active, the spatial distribution of the fields of each transmitter will be different from that of the composite field. A suitable technique would consist of attempting to identify a location wherein the greatest indicated composite field exists, when all transmitters are active, and then to re-measure at this point with only individual transmitters operating. When performing such measurements, however, the uncertainty associated with the summed value of measured fields of the individual transmitter operation may actually be greater than if the composite field were measured with all transmitters active since the individual fields will typically be smaller in magnitude than the composite value.

Modeling of RF Fields, 2D vs. 3D Visual Display Methods

19. One comment suggested that the FCC should require the use of field calculation software that provides three dimensional (3D) representations of the resultant fields. The argument was that the use of two dimensional (2D) methods could be confusing to individuals interpreting the analysis results. Any form of analysis results can appear confusing to individuals who are not familiar with a particular display format. In fact, 2D presentation methods are generally less confusing in many cases than 3D display formats. From my personal experience, proper labeling of displays is entirely adequate to eliminate misapplication of the graphical results of 2D types of presentations of calculated RF fields. Both 2D and 3D display modes have their individual advantages and disadvantages and should be employed with attention to appropriate explanations. It would seem inappropriate to limit the way that various analysis assessments could be presented since a single approach will not necessarily always be the optimum way of communicating the results.

Qualified Personnel

20. The suggestion has been made by one respondent to the NPRM that only licensed engineers be allowed to conduct and/or oversee RF compliance assessments. This argument has been made, apparently, out of a concern that individuals who are not licensed as engineers are likely to not be capable of understanding the intricacies and

complexities of such assessments and, hence, more likely to arrive at erroneous conclusions as to compliance. This suggestion is inappropriate for at least several reasons:
(a) the use of licensed engineers for preparation of RF compliance documents does not ensure that the person is qualified;
(b) examination of applicants for state licensing of engineers does not include any requirement of specialized knowledge in RF field measurements or field characterization;
(c) the FCC does not have any requirement that licensed engineers must prepare applications for FCC licenses for construction and operation of broadcast stations; requiring RF compliance assessments, which represent only one element of the broadcast station licensing process, to be prepared by licensed engineers is inconsistent with the licensing process;

21. While a requirement that any individual submitting materials in connection with an FCC matter related to RF compliance should be a licensed engineer is inappropriate, it is appropriate that such materials include a statement of qualifications. This statement can provide useful information to permit evaluation of the individual's background and experience in the relevant technical area. This is customary process for engineering applications for new or modified broadcast stations.

Use of Actual Power for Near-Field Calculations, not EIRP

22. One respondent recommended that near-field calculations for estimating RF fields in compliance evaluations should use actual power delivered to the antenna rather than effective isotropic radiated power (ERIP). This is a very sound statement supported by detailed electromagnetic field analyses wherein it can be shown that actual power and physical size of the antenna are two most important factors driving near-field field magnitudes. As is apparent in OET Bulletin 65, near-field calculations do not employ antenna gain since gain is a far-field characterization of antennas and is not applicable in the close vicinity of an antenna. This observation should be relevant in establishing the criteria for those systems that could be categorically excluded from routine evaluation. Rather than using EIRP, or ERP, as the important criterion for determining if RF fields might exceed the MPE limits near the antenna, and, hence, whether the antenna could be categorically excluded, a more accurate assessment would be based on a combination of antenna input power and antenna physical size.

MPEs are "Demonstrably inadequate" and "few long term studies"

23. Two comments among the responses to the NPRM state that the MPE limits used by the FCC are demonstrably inadequate for long-term exposure and that there are few long-term studies to back up the MPE limits. Such statements seem to suggest that substantial uncertainty exists about the adequacy of the protection that the present MPE limits offer to exposed individuals. Such a view ignores the very substantial increase in the breadth and depth of the present database of peer reviewed scientific reports of studies of

biological effects. Review of this database supports the compelling contention, based on the weight of evidence, that there is far less uncertainty in our knowledge of the threshold for adverse biological effects of RF fields today than that which existed at the time the present MPE limits were recommended by both IEEE and the NCRP. For example, during the past approximate 13 years, since the publication of the current IEEE standard, some 36 long-term studies in animals have been produced, all except one finding no significant effects. This is to be contrasted with the discordant picture from only 7 long-term studies available 13 years ago. While additional research data should help solidify current insights on the hazards associated with RF exposure, we much not lose sight of the substantial advances in our knowledge made since publication of the last IEEE standard and the publication of the exposure criteria recommended by the NCRP, upon which the present FCC MPE limits are based. A large database of published research papers on biological effects of RF exposure can be found on the World Health Organization web site at http://www.who.int/peh-emf/research/database/en/.

Induced and Contact Currents

24. Presently, the FCC does not include limits on contact and/or induced body RF currents. At the time the FCC elected not to include such currents in its regulations, limited instrumentation was available for performing such measurements. Today, contact and induced current measuring devices are commercially available and routinely used in performing compliance evaluations against the IEEE standard. Limits on these currents in the IEEE C95.1 standard (200 mA for controlled environments) can be related directly to limiting the localized SAR in the ankles and wrists. Prior to the FCC's issuance of the present RF rules, the Occupational Safety and Health Administration (OSHA) wrote to the FCC[1] generally endorsing the proposed action of the FCC in adopting its new rules but encouraging the commission to also include limits for induced foot and contact currents. The FCC should now include contact and induced currents in any revised rules.

25. The magnitude of induced current in the body of a standing adult for frequencies up to 40 MHz is given approximately by

$$I = 0.35 mA/(V/m)/(MHz)$$

At 30 MHz, for example, this formula shows that exposure to an RF field at the FCC MPE limit for occupational exposure (61.4 V/m) will result in approximately 645 mA flowing in the body and legs. This is more than three times the IEEE MPE limit and demonstrates the inconsistence between RF field MPE limits and local SAR restrictions; i.e., compliance with the field limits does not necessarily ensure that induced current limits will be in compliance.

[1]Letter from Gregory J. Baxter, Acting Director, Directorate of Technical Services, Occupational Safety and Health Administration, U.S. Department of Labor to Richard M. Smith, Chief Engineer, Office of Engineering and Technology, Federal Communications Commission, August 2, 1996.

Respectfully submitted on January 6, 2004, by:

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